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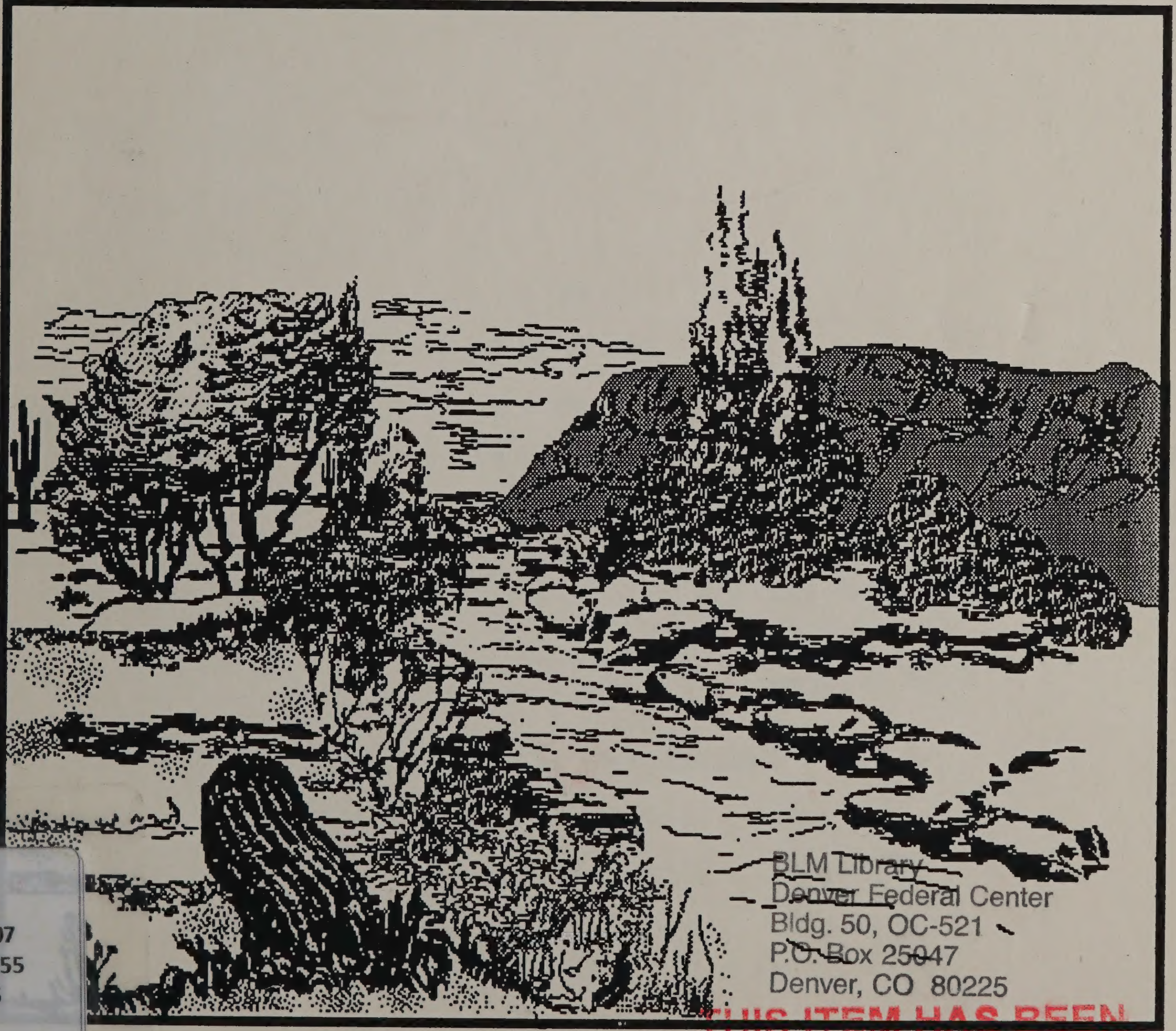
Assessment of Water Resource Conditions In Support of Instream Flow Water Rights

Bill Williams River, Arizona



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Assessment Of Water Resource Conditions
In Support Of
Instream Flow Water Rights

Bill Williams River, Arizona

by

Barry A. Long

and

Rebecca Peck

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Executive Summary

The Bill Williams Riparian Management Area (BWRMA) is located in the Basin and Range physiographic province of western Arizona. The BLM-managed reach begins at Alamo Dam and extends approximately 20 miles downstream to Planet Ranch. Flows in the river have been regulated by Alamo Dam since 1969. Post-dam annual flows have averaged 153 cubic feet per second (cfs) or 111,177 acre-feet (AF); of that roughly two thirds is stormflow release.

In 1988, the BLM applied for an instream flow appropriation below Alamo Dam in response to the City of Scottsdale's filing for a right to all unappropriated releases from the reservoir. The BLM recognizes that maintenance of in-channel flows in the Bill Williams River is the inextricable link that serves to protect water-dependent uses and values within the BWRMA. This compendium is an assessment of data from subsequent field reconnaissance and analysis that quantifies BLM instream flow needs in the basin. The approach that was used for quantifying water needs was based upon combining water balance techniques (assuming controlled inputs and measured losses and throughflow), channel cross-section data, and fish requirement evaluations. As a result, the BLM requests that water right application No. 33-94245 be modified downward from 109,190 AF to 25,548 AF and apportioned according to the monthly release schedule presented in Table 2.

Assessment of Water Resource Conditions in Support of Instream Flow Water Rights for the Bill Williams River, Arizona

Introduction

On 27-30 June 1988 U.S. Bureau of Land Management (BLM) personnel conducted field studies in the Bill Williams River watershed to quantify instream flow (ISF) needs to justify BLM water right application No. 33-94245. The original water right application was filed with the Arizona Department of Water Resources on April 4, 1988. Fisheries, wildlife, riparian vegetation, and recreation values in the Bill Williams River are dependent on maintenance of minimum stream flows below Alamo Dam. Instream flow objectives for the Bill Williams Riparian Management Area (BWRMA) were as follows:

1. Maintain adequate stream flows to provide for sufficient fish abundance and biomass for two nesting pairs of bald eagles downstream of Alamo Dam.
2. Maintain adequate stream flows to provide for sufficient leopard frog and fish abundance and biomass for four pioneer nesting pairs of black hawks downstream of Alamo Dam.
3. Maintain adequate stream flows and manage livestock to establish 200 acres of gallery cottonwood/willow habitats between Alamo Dam and Planet Ranch for riparian obligate species in the next ten years.
4. Maintain adequate stream flows and manage livestock to provide natural cottonwood and willow establishment which exceeds harvest by beaver.
5. Maintain adequate stream flows and manage livestock to provide natural cottonwood and willow sapling production sufficient for the establishment of five beaver dam structures below Alamo Dam within the next five years.
6. Maintain adequate stream flows and manage livestock to establish 800 acres of mesquite bosque habitats for riparian obligate species in the next ten years.

Physical Setting

A. Physiographic Features

The Bill Williams drainage is divided nearly equally into two physiographic provinces; the dividing line lies east of, and roughly parallels highway U.S. 93. The eastern upper half of the watershed lies within the Central Highlands Province. The western, lower half of the watershed, in which the BWRMA occurs, lies within the Basin and Range Lowlands Province (Figure 1).

The Basin and Range Lowlands Province is typified by north to northwest trending mountain ranges separated by alluvial basins. The lowest drainage elevation, at the confluence with the Colorado River, lies at about 1600 feet. This contrasts with the more rugged

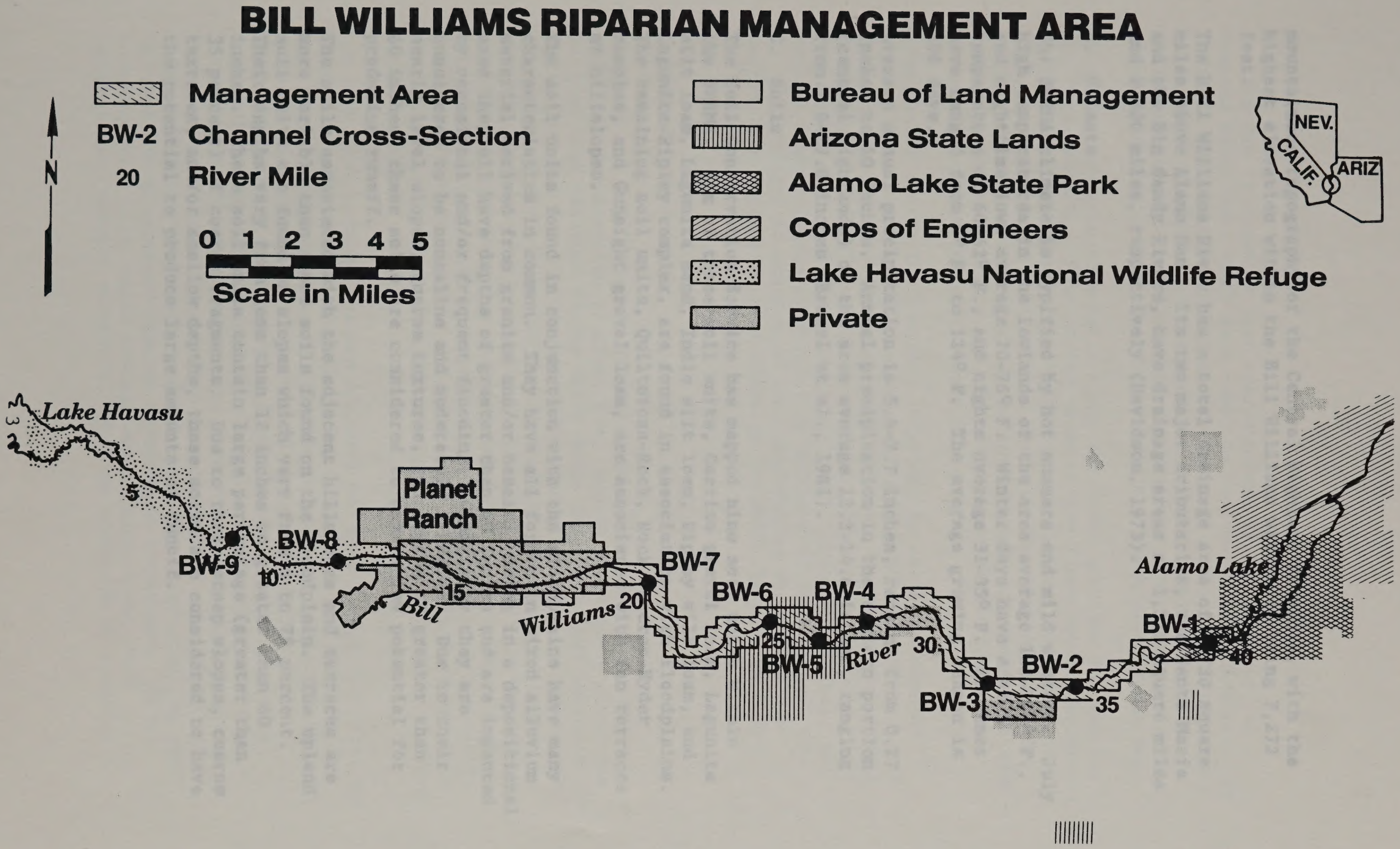

BILL WILLIAMS RIPARIAN MANAGEMENT AREA
Management Area
BW-2 Channel Cross-Section
20 River Mile
Bureau of Land Management
Arizona State Lands
Alamo Lake State Park
Corps of Engineers
Lake Havasu National Wildlife Refuge
Private
N
0 1 2 3 4 5
Scale in Miles
NEV.
CALIF.
ARIZ
Lake Havasu
Planet Ranch
Bill
Williams
River
Alamo Lake
BW-1
BW-2
BW-3
BW-4
BW-5
BW-6
BW-7
BW-8
BW-9
2
3
5
10
15
20
25
30
35
40

Figure 1.

mountainous topography of the Central Highland Province, with the highest elevation within the Bill Williams watershed being 7,272 feet.

The Bill Williams River has a total drainage area of 4,730 square miles above Alamo Dam. Its two major tributaries, the Santa Maria and the Big Sandy Rivers, have drainage areas of 1,520 square miles and 2,800 miles, respectively (Davidson, 1973).

B. Climate

The BWRMA climate is typified by hot summers and mild winters. July high temperatures in the lowlands of the area average 103-108° F., and nighttime lows average 70-76° F. Winter days have a high temperature of 60-62° F., and nights average 31-35° F. Extremes have ranged from 9° F. to 124° F. The average growing season is 256 days.

Average annual precipitation is 5.4-7.7 inches, ranging from 0.27 inches to 10 inches. Annual precipitation in the eastern portion (central highlands) of the area average 12.3-14.6 inches, ranging from 2.8-27.0 inches (Brazel et al., 1981).

C. Soils

The Soil Conservation Service has mapped nine soil units within the BWRMA. Six of these soil units, Carrizo gravel loam, Lagunita silt loam, Lagunita sand, Indio silt loam, Ripley silt loam, and Lagunita-Ripley complex, are found in association with floodplains. The remaining soil units, Quiltotosa-Rock, Rock outcrop-Hyder complex, and Gunsight gravel loam, are associated with fan terraces of hillslopes.

The soil units found in conjunction with the floodplains have many characteristics in common. They have all formed in mixed alluvium material derived from granite and/or basalt. Being in a depositional area they all have depths of greater than 60 inches and are impacted by occasional and/or frequent flooding. Chemically they are considered to be nonsaline and moderately alkaline. Due to their nearly level slopes, coarse textures, and depths of greater than 60 inches, these soils are considered to have a low potential for producing runoff.

The soils associated with the adjacent hillslopes and terraces are more variable than those soils found on the floodplain. The upland soil units are found on slopes which vary from 5 to 75 percent. Their depths vary from less than 12 inches to greater than 60 inches. These soil units contain large percentage (greater than 35 percent) of coarse fragments. Due to their steep slopes, coarse textures, and/or shallow depths, these soils are considered to have the potential to produce large amounts of runoff.

River Based Recreation

The BLM has recommended that approximately 16,000 acres in the Swansea Wilderness Study Area (WSA) be designated as wilderness. The proposed action includes six miles of the Bill Williams River within the BWRMA. Another 40,000 acres in the Rawhide Mountains WSA are being recommended for wilderness designation. This includes seven miles of the Bill Williams River within the BWRMA below Alamo Dam.

Excellent opportunities exist along the river corridor for hunting and bird watching. Even during years of low flood control releases, high quality backpacking opportunities (similar to that found in Aravaipa Canyon) are available in the upper canyon. Minimum flow releases would make backpacking relatively safe and convenient even during the summer. There are presently no developed recreation sites along the river below Alamo Dam.

Consumptive recreation (hunting, fishing) is second to outdoor recreational vehicle (ORV) use along the Bill Williams River. The most common uses are dove and quail hunting. Deer are also hunted along the river, but to a lesser degree. Fishing is limited to the canyon area directly below Alamo Dam. Kayaking, rafting, and canoeing are suitable at flood-flow releases of 1000 to 2000 cfs. It is important to understand that consumptive as well as non-consumptive recreation uses exist in the BWRMA because of water availability.

Hydrologic Assessment

Flows in the Bill Williams River became regulated during 1969 following construction of Alamo Dam. Annual flows below Alamo Dam at USGS gage 09426000 during Water Years (WY) 1970-1986 averaged 153 cubic feet per second (cfs), ranging from a low of 2.05 cfs in 1975 to a high of 888 cfs in 1980. Total annual discharge averaged 111,177 acre-feet (AF), ranging from 1490 AF in 1975 to 644,500 AF in 1980. A flow duration analysis for low flow exceedence during the post-dam period is presented in Figure 2. The 50th percentile indicate flows that 50% of the time would be less than or equal to the values shown on the Y-axis and represent median values of normal monthly means.

In June 1988, a water balance approach was used to measure gains and losses in surface flow from Alamo Dam downstream to Planet Ranch and the Lake Havasu National Wildlife Refuge. A three-week 100 cfs release from Alamo Dam was requested to assure surface flow throughout the 21 mile reach to Planet Ranch. Stream segments were delineated using topographic maps, geologic maps, and aerial photographs. Sampling sites were selected at segment boundaries at known access points. Streamflow was measured at nine sites using a Marsh McBirney flow meter and seven cross-section profiles were surveyed using standard channel measurement techniques. Other resource data (i.e. basin geology and geomorphology, bank composition, channel substrate, type and condition of riparian

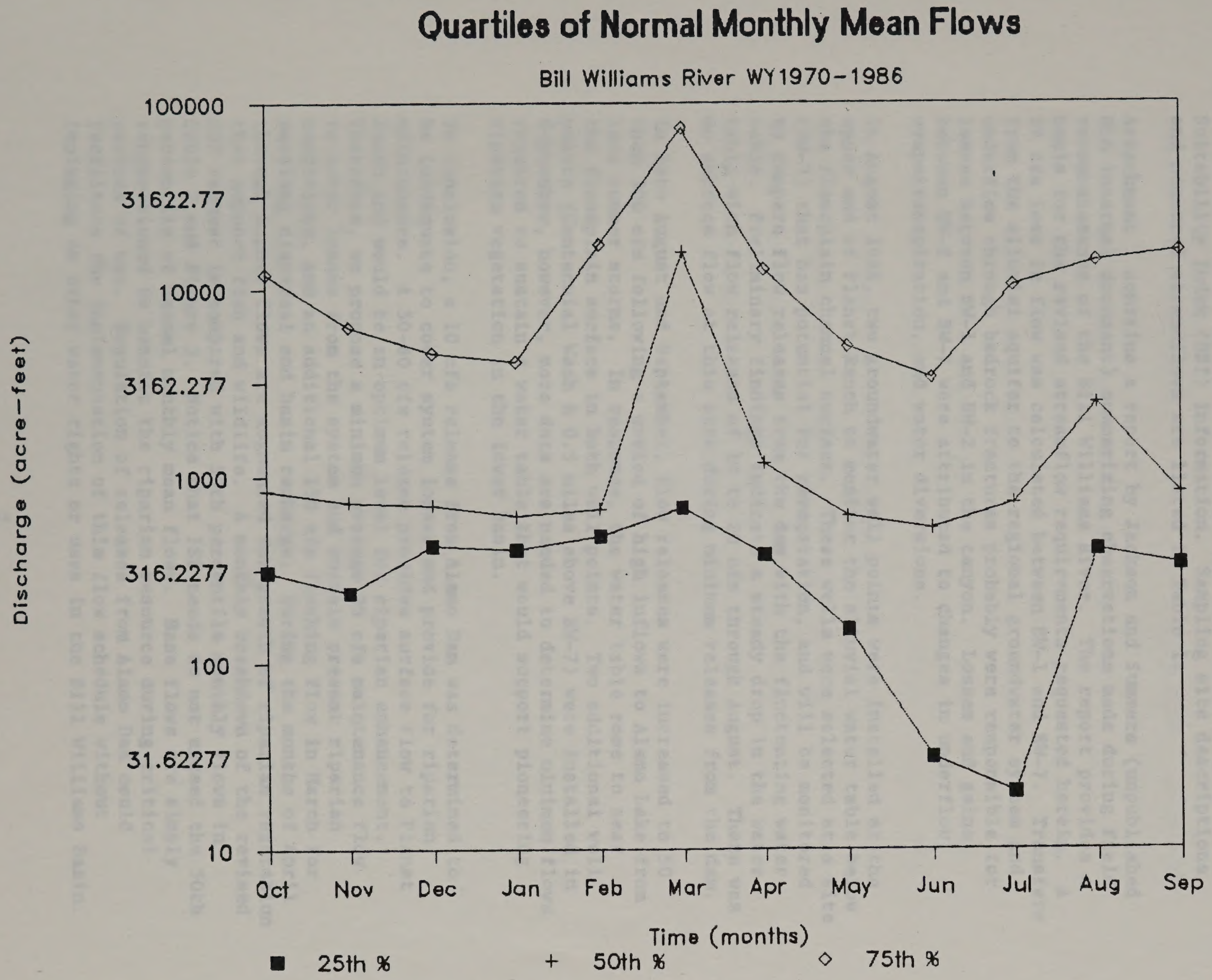

Quartiles of Normal Monthly Mean Flows
Bill Williams River WY1970-1986
Discharge (acre-feet)
100000
31622.77
10000
3162.277
1000
316.2277
100
31.62277
10
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Time (months)
■ 25th %
+ 50th %
◇ 75th %

Figure 2.

vegetation, presence of riparian species, and grazing impacts) were collected to focus future resource studies. Streamflow needs for fish in the Bill Williams River were generated using results from past BLM inventories and U.S. Fish and Wildlife Service Habitat Suitability Index (HSI) information. Sampling site descriptions and measured streamflows are listed in Table 1.

Attachment 1 contains a report by Jackson and Summers (unpublished BLM internal document) summarizing observations made during field reconnaissance of the Bill Williams River. The report provides a basis for the revised streamflow requirements requested herein. A 29 cfs loss in flow was calculated between BW-1 and BW-7. Transfers from the alluvial aquifer to the regional groundwater system and underflow through bedrock fractures probably were responsible for losses between BW-1 and BW-2 in the canyon. Losses and gains between BW-2 and BW-7 were attributed to changes in underflow, evapotranspiration, and water diversions.

In August 1988, two groundwater well points were installed at the upper end of Planet Ranch to monitor the alluvial water table below the floodplain channel surface. These wells were selected at a site (BW-7) that has potential for revegetation, and will be monitored to compare flow releases from the dam with the fluctuating water table. Preliminary findings indicate a steady drop in the water table with flow releases of 10 to 20 cfs through August. There was no surface flow at this site during minimum releases from the dam.

In late August and September, flow releases were increased to 50 then 300 cfs following a period of high inflows to Alamo Lake from late summer storms. In response, the water table rose to near the floodplain surface in both well points. Two additional well points (Centennial Wash & 0.5 miles above BW-7) were installed in September, however, more data are needed to determine minimum flows required to sustain a water table that would support pioneering riparian vegetation in the lower basin.

In conclusion, a 10 cfs release from Alamo Dam was determined to be inadequate to cover system losses and provide for riparian maintenance. A 50-60 cfs release provides surface flow to Planet Ranch and would be an optimum level for riparian enhancement. Therefore, we propose a minimum average 25 cfs maintenance flow to cover losses from the system and sustain present riparian conditions, and an additional 150 cfs flushing flow in March for seedling dispersal and basin recharge. During the months of April through August flows are augmented for growth of riparian vegetation that support fish and wildlife. A monthly breakdown of the revised ISF request is compared with 50th percentile monthly flows in Table 2 and Figure 3. Notice that ISF needs do not exceed the 50th percentile of normal monthly mean flows. Base flows are simply reapportioned to benefit the riparian resource during critical periods of use. Regulation of releases from Alamo Dam could facilitate the implementation of this flow schedule without impinging on other water rights or uses in the Bill Williams Basin.

Table 1. Sampling site descriptions and measured stream flows, Bill Williams River June 27-30, 1988.

SITE ID	DESCRIPTION	RIVER MILE	DISCHARGE (cfs)
BW-1	Below Alamo Dam @ USGS Gage 4260	39.5	105
BW-2	Above Lincoln Ranch	34.4	91
BW-3	Below Lincoln Ranch	32.1	86
BW-4	At Wayne Pitrat Ranch	27.5	94
BW-5	At Pipeline Crossing	26.5	94
BW-6	Between Pipeline and Swansea	25.1	86
BW-7	At Centennial Wash	20.0	76
BW-8	At Mohave Wash	12.0	11
BW-9	At Kohen Ranch	8.25	6

Table 2. Comparison of revised BLM Instream Flow water right request with 50th percentile monthly mean flows for WY1970-1986, Bill Williams River.

MONTH	ISF REQUEST		50TH PERCENTILE	
	(cfs)	(acre-feet)	(cfs)	(acre-feet)
Oct	10	615	13.6	836
Nov	10	595	12.1	720
Dec	10	615	11.3	695
Jan	10	615	10.0	615
Feb	10	555	12.0	666
Mar	150	9,223	255.9	15,735
Apr	40	2,380	19.5	1,160
May	40	2,460	10.0	615
Jun	40	2,380	8.8	524
Jul	40	2,460	11.6	713
Aug	40	2,460	40.3	2,478
Sep	20	1,190	13.7	815
		25,548		25,572

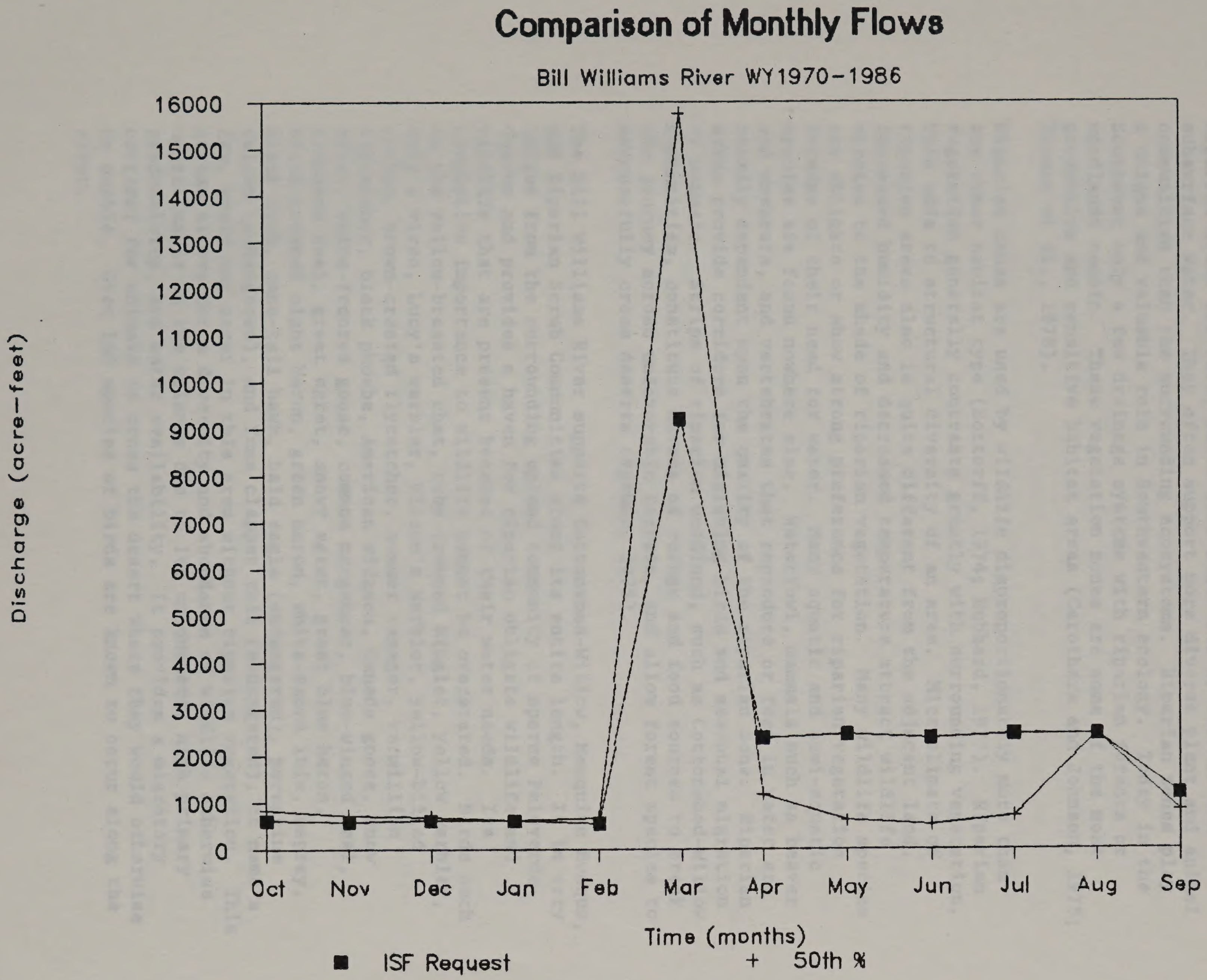

Comparison of Monthly Flows
Bill Williams River WY1970-1986
Discharge (acre-feet)
16000
15000
14000
13000
12000
11000
10000
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Time (months)
■ ISF Request
+ 50th %

Figure 3.

Biological Assessment

Riparian areas are rare, oasis-like zones fed by surface and subsurface water. They often support more diverse plant and animal communities than the surrounding ecosystems. Riparian zones play a unique and valuable role in Southwestern ecology. Today in the Southwest only a few drainage systems with riparian forests or woodlands remain. These vegetation zones are some of the most productive and sensitive habitat areas (Carothers and Johnson, 1975; Thomas et al., 1978).

Riparian zones are used by wildlife disproportionately more than any other habitat type (Bottorff, 1974; Hubbard, 1977). Riparian vegetation generally contrasts greatly with surrounding vegetation. This adds to structural diversity of an area. Microclimate of riparian areas also is quite different from the adjacent land. Increased humidity and decreased temperature attract wildlife species to the shade of riparian vegetation. Many wildlife species are obligate or show strong preference for riparian vegetation because of their need for water. Many aquatic and semi-aquatic species are found nowhere else. Waterfowl, mammals such as beaver and muskrats, and vertebrates that reproduce or feed in water are totally dependent upon the quality of the riparian zone. Riparian areas provide corridors for migrating birds and seasonal migration of mammals. Strips of riparian woodland, such as Cottonwood-Willow communities, constitute havens of refuge and food sources to break the journey across unfavorable terrain, and allow forest species to successfully cross deserts (Sprunt, 1975).

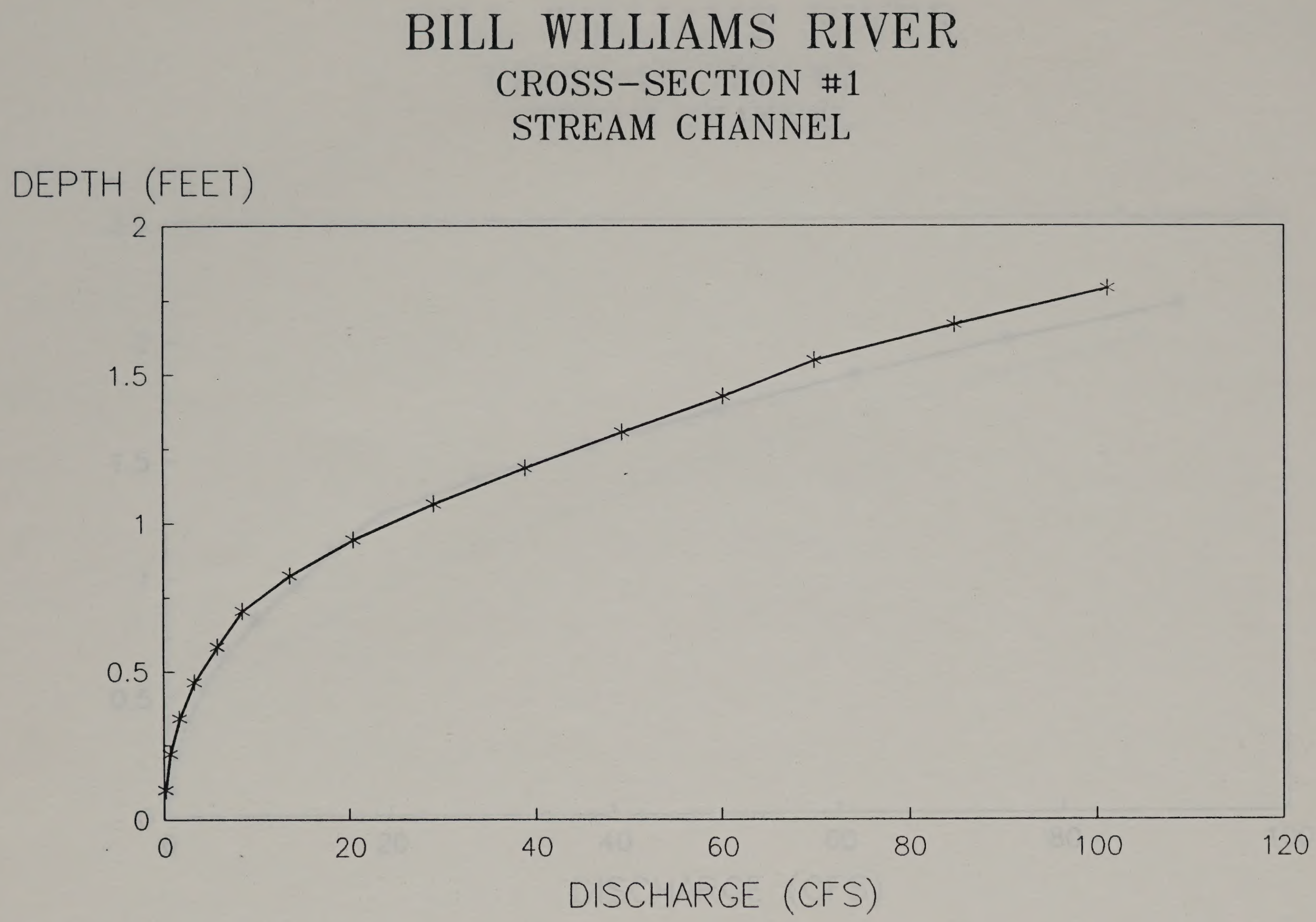
The Bill Williams River supports Cottonwood-Willow, Mesquite Bosque, and Riparian Scrub Communities along its entire length. It is very unique from the surrounding upland community of sparce Paloverde-Cactus and provides a haven for riparian obligate wildlife and wildlife that are present because of their water needs. Its cumulative importance to wildlife cannot be overstated. Birds such as the yellow-breasted chat, ruby-crowned kinglet, yellow warbler, Bell's vireo, Lucy's warbler, Wilson's warbler, yellow-billed cuckoo, brown-crested flycatcher, summer tanager, vermillion flycatcher, black phoebe, American widgeon, Canada goose, snow goose, white-fronted goose, common merganser, blue-winged teal, cinnamon teal, great egret, snowy egret, great blue heron, black-crowned night heron, green heron, white-faced ibis, osprey, black hawk, zone-tail hawk, bald eagle (endangered), peregrine falcon (endangered), and Yuma clapper rail (endangered), to name a few, would not occur in this area without riparian vegetation. This stream allows for a diversity and abundance of wildlife otherwise unattainable on the uplands due to its uniqueness, high primary productivity, and water availability. It provides a migratory corridor for animals to cross the desert where they would otherwise be unable. Over 100 species of birds are known to occur along the river.

The presence of a fisheries is also extremely important and rare in Arizona. Fishes that are known to exist in the Bill Williams River include: carp, green sunfish, mosquitofish, red shiner, channel catfish, and bullhead (Kepner, 1980; pers. comm. Kepner, 1988). This fisheries supports a nesting pair of bald eagles at the upper end of the river. Flow requirements for fish were estimated by comparing preferred depths for reproduction with depth versus discharge relationships that were generated from survey data collected in June 1988. Depth preferences of larger fish species such as channel catfish, bullhead, and carp ranged from one to six feet (McMahon and Terrell, 1982; Stuber, 1982; Edwards and Twomey, 1982). For the minimum value of one foot in depth, base flows between 10 and 50 cfs would be required in the river from cross-section BW-1 to cross-section BW-5 (Figures 4-8). Also, wetted perimeter versus discharge data suggest that base flows between 10 and 32 cfs (inflection point) would provide adequate habitat for fish above cross-section BW-5 (Figures 9-13).

Riparian vegetation in the Bill Williams River drainage represents 30 percent of the historical amount once present (Ohmart, 1979). However, the potential for riparian habitat development and continued maintenance is very high. With the requested flows and control of livestock grazing, riparian vegetation in this area would respond with rapid growth rates and proliferation into new growth areas. It is expected that the herbaceous layer would significantly increase throughout the floodplain. Many areas that currently do not support woody riparian species or that support a depauperate woody riparian community would be expected to respond favorably.

Certain stream segments have more potential than others. The segment nearest to Alamo Dam has the lowest potential due to the lack of sediment load in the water. The channel in this area has cut down to bedrock and is not expected to build again as long as the dam is present. The supply of sediment is stopped by the dam. Further down the drainage (starting at station BW-2) the sediment load increases due to supply from side drainages. Eventually, floodplain building would occur as riparian vegetation increases and traps the sediment in place. From station BW-4 downstream the channel is actively aggrading. This area already contains a Cottonwood-Willow community that is quite dense but lacks an herbaceous layer and a good mix of size classes of willows and cottonwoods.

An improvement in the wildlife community that exists along the Bill Williams River would parallel vegetative habitat improvement. With vegetative recovery there would be a significant increase in the diversity and abundance of wildlife within the river corridor. This would especially benefit riparian obligate species as listed above.



N = .098

Figure 4.

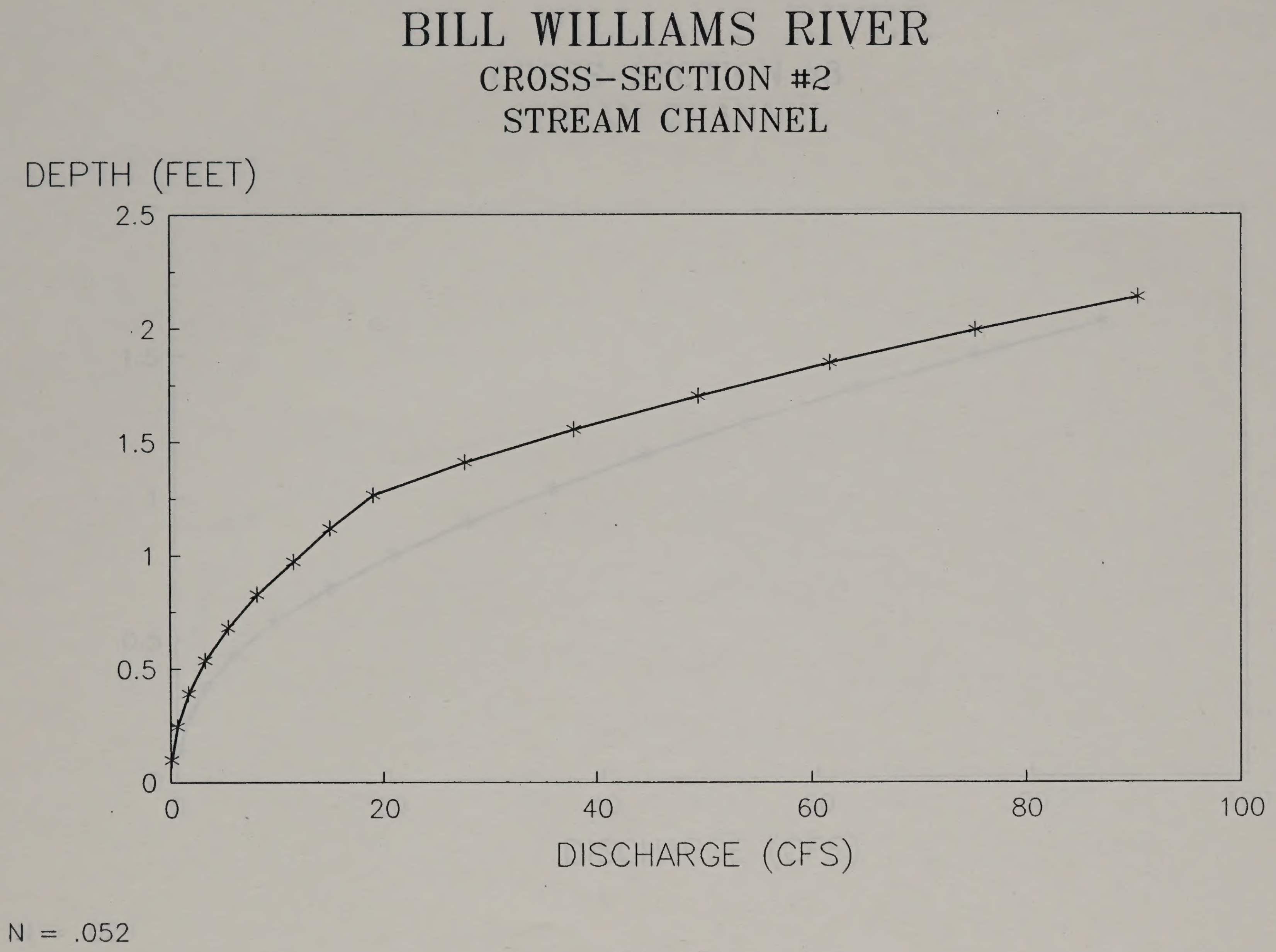
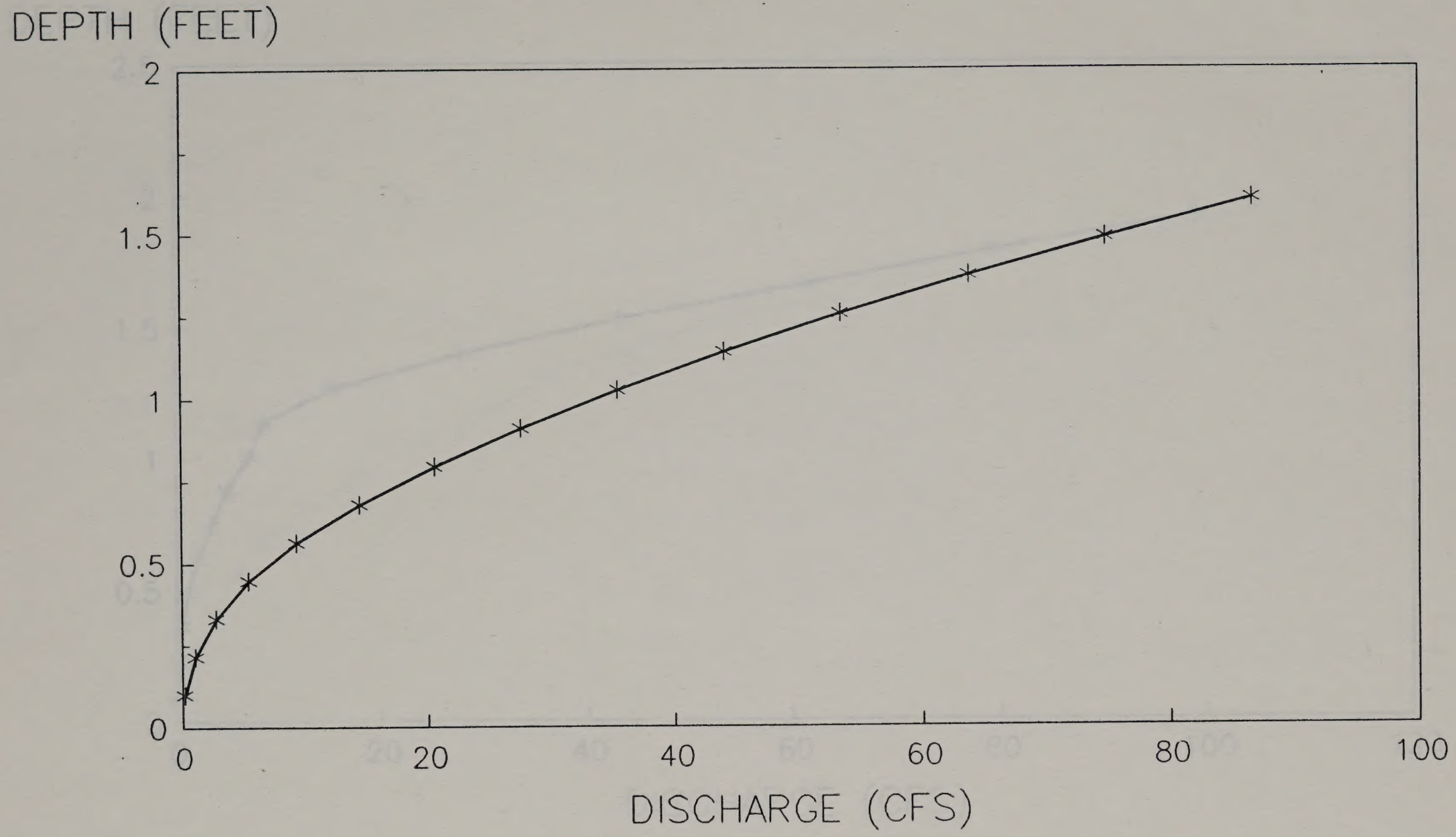

BILL WILLIAMS RIVER
CROSS-SECTION #2
STREAM CHANNEL
DEPTH (FEET)
2.5
2
1.5
1
0.5
0
0
20
40
60
80
100
DISCHARGE (CFS)
N = .052

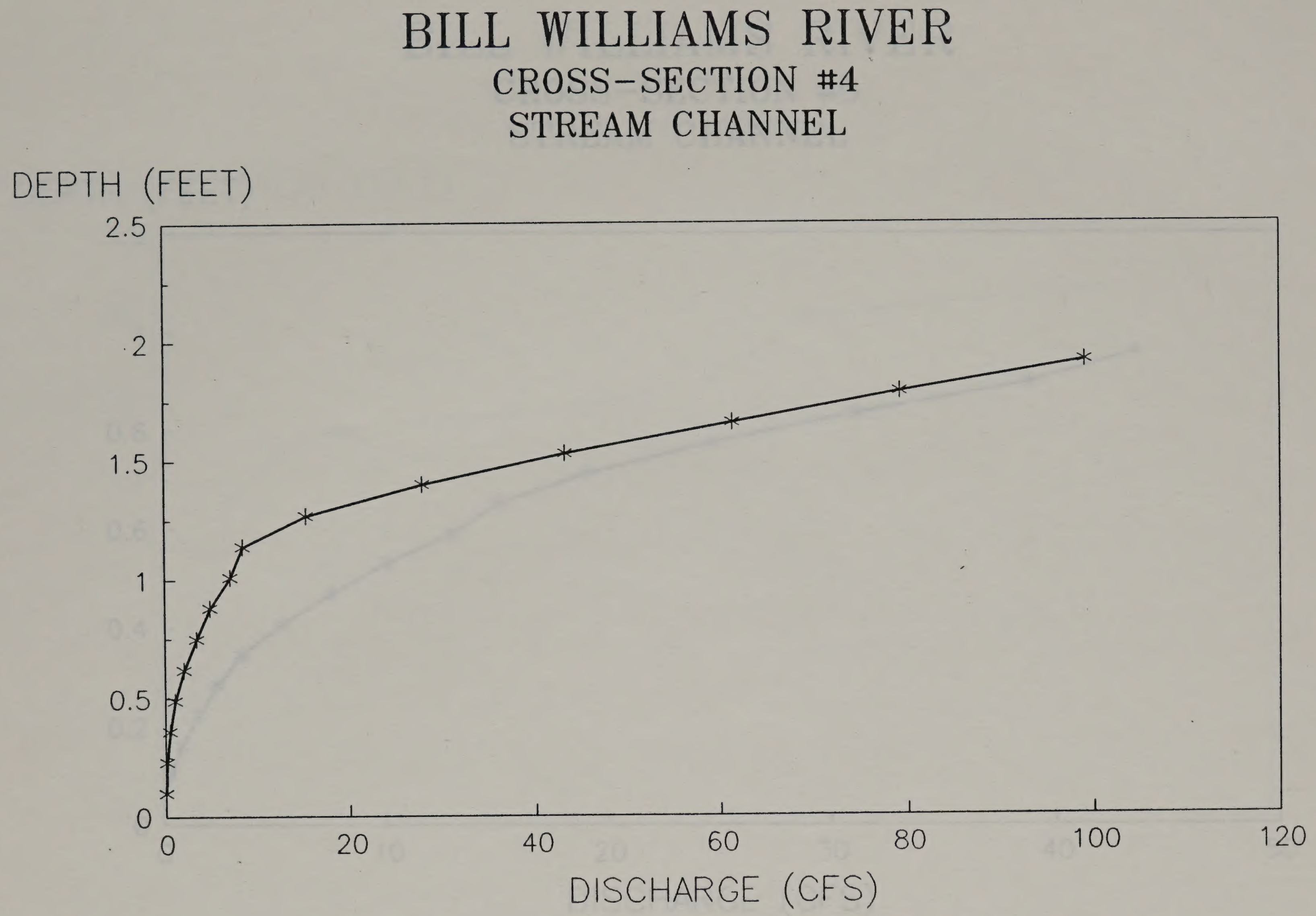
Figure 5.

BILL WILLIAMS RIVER
CROSS-SECTION #3
STREAM CHANNEL



N = .029

Figure 6.


BILL WILLIAMS RIVER
CROSS-SECTION #4
STREAM CHANNEL

N = .029

Figure 7.

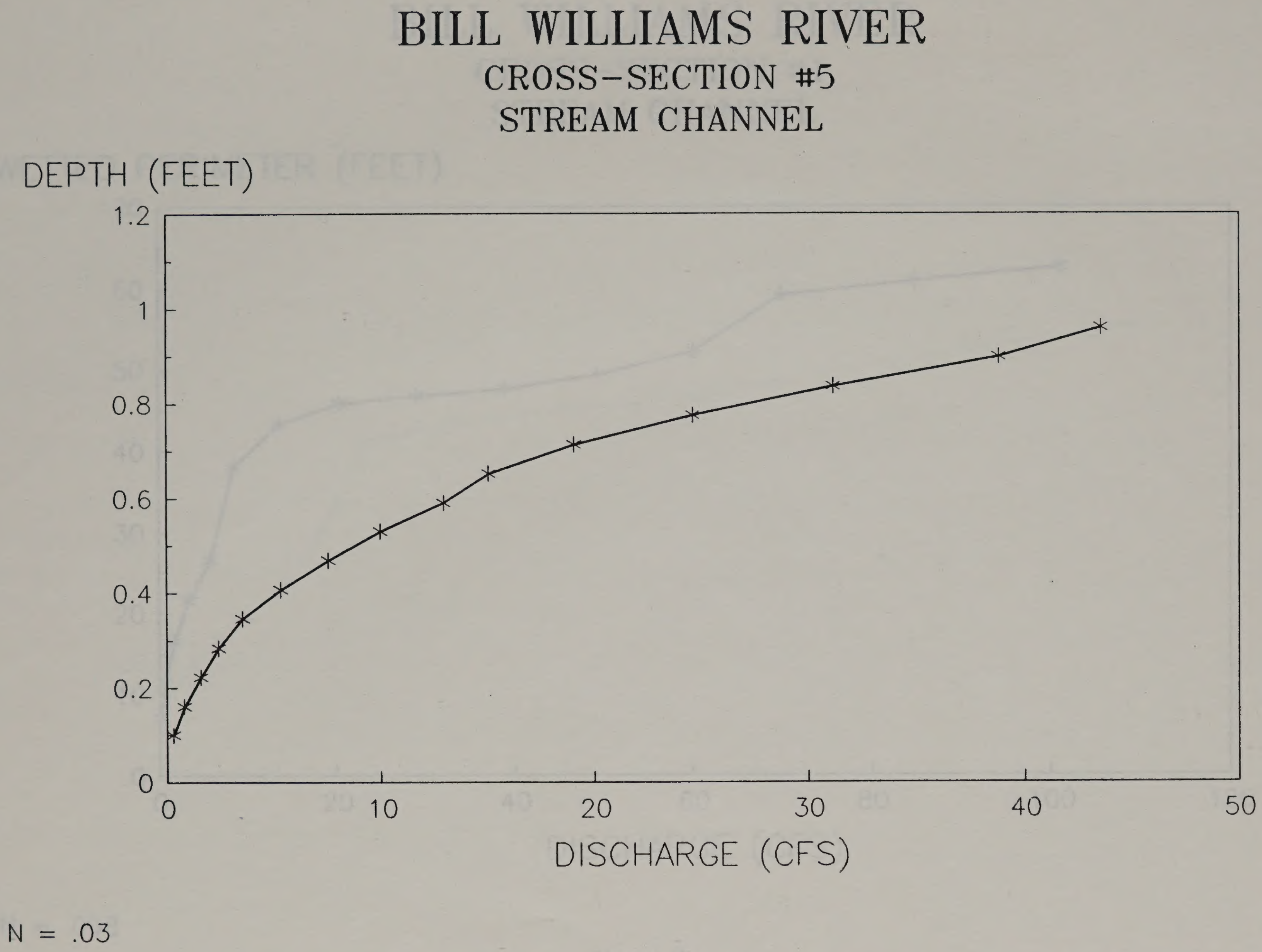
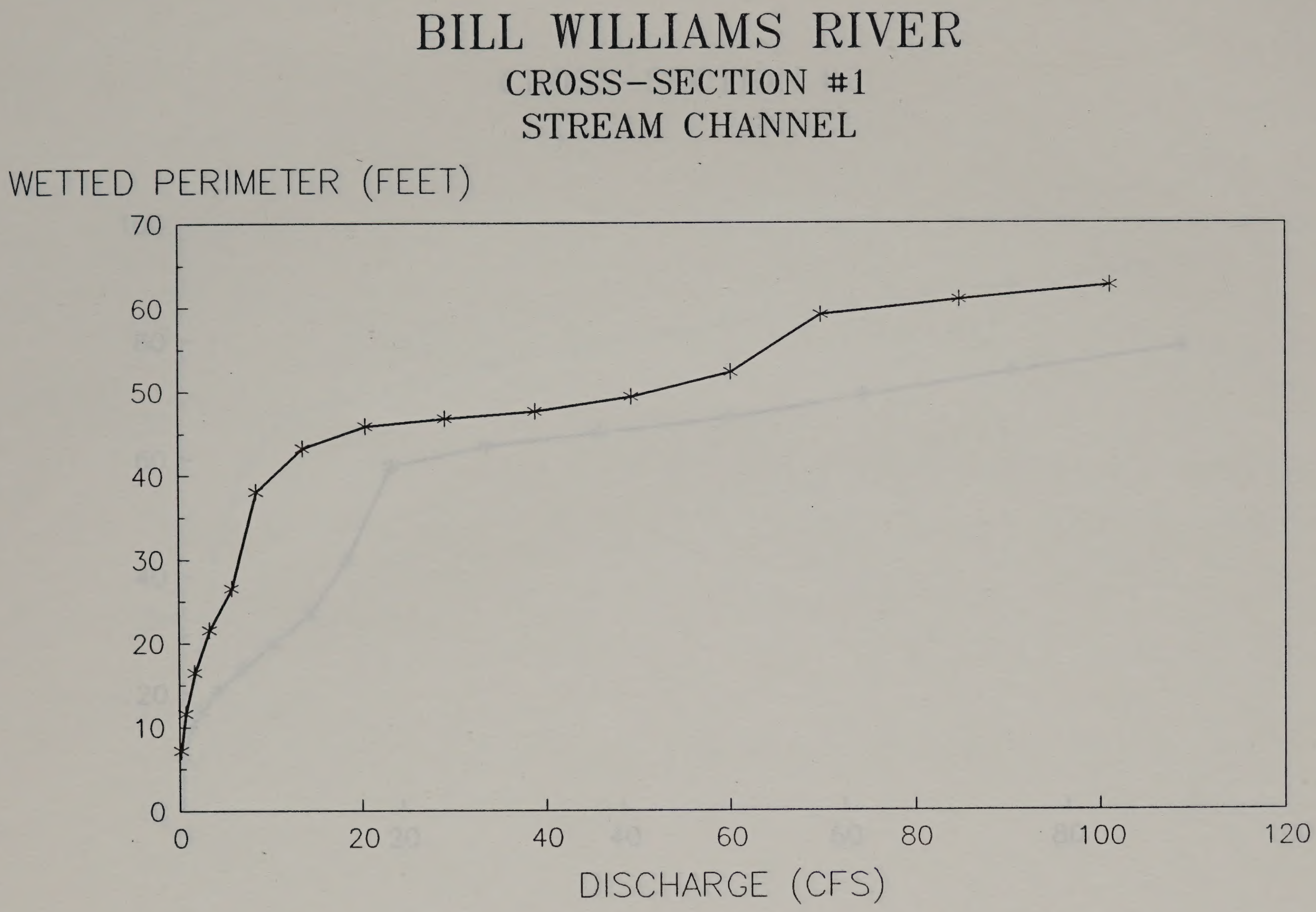
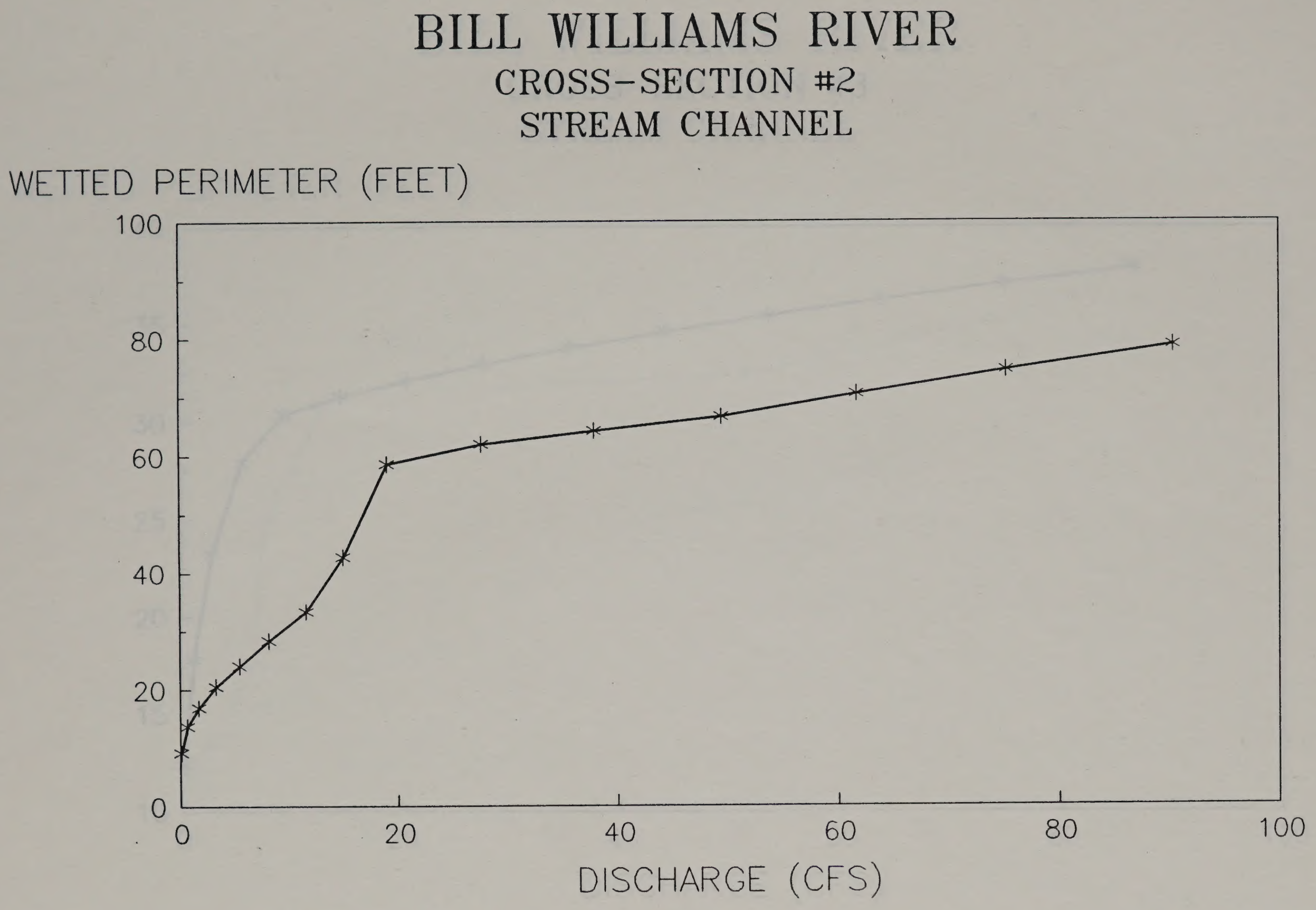

BILL WILLIAMS RIVER
CROSS-SECTION #5
STREAM CHANNEL
DEPTH (FEET)
1.2
1
0.8
0.6
0.4
0.2
0
0
10
20
30
40
50
DISCHARGE (CFS)
N = .03

Figure 8.



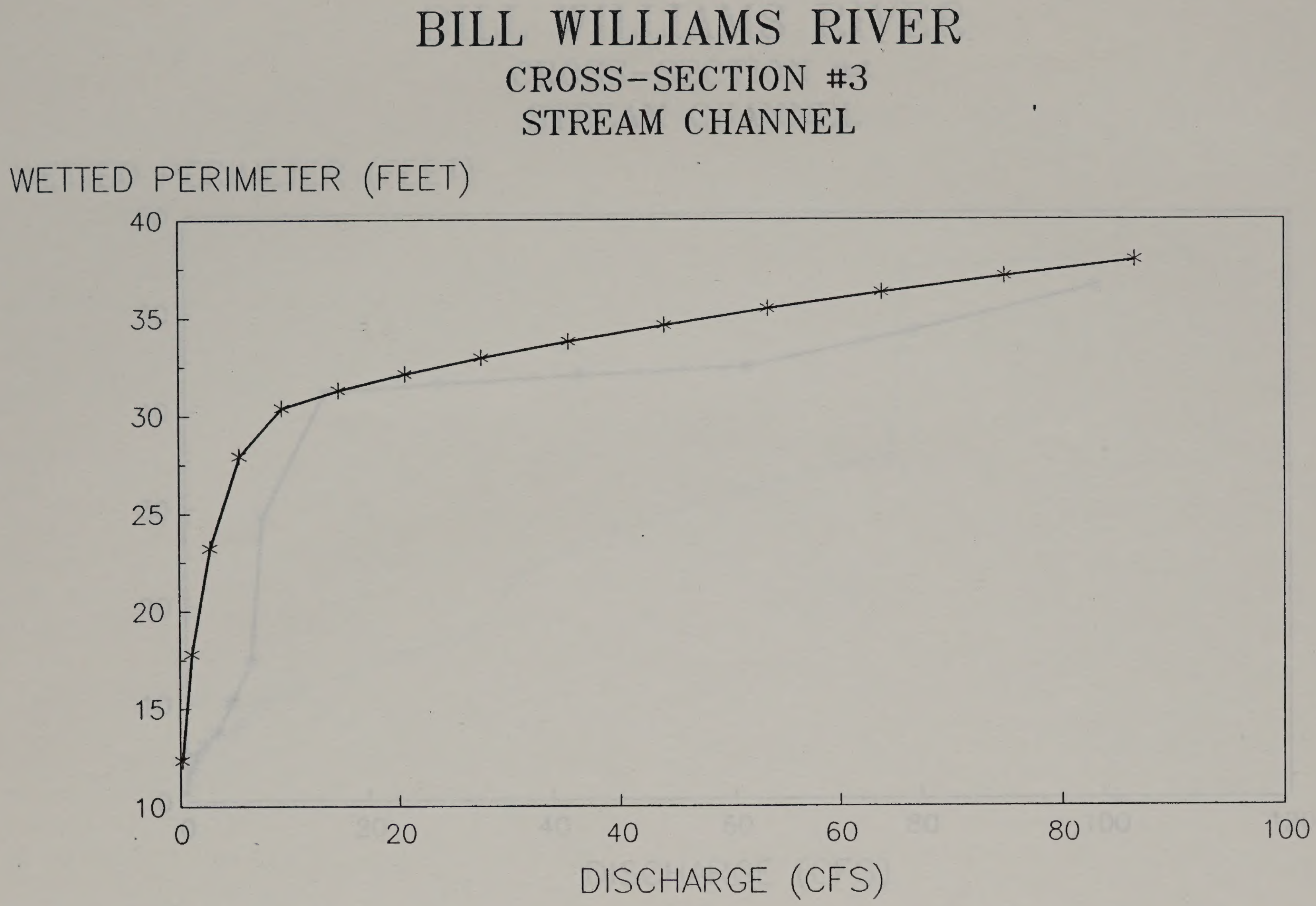
N = .098

Figure 9.



N = .052

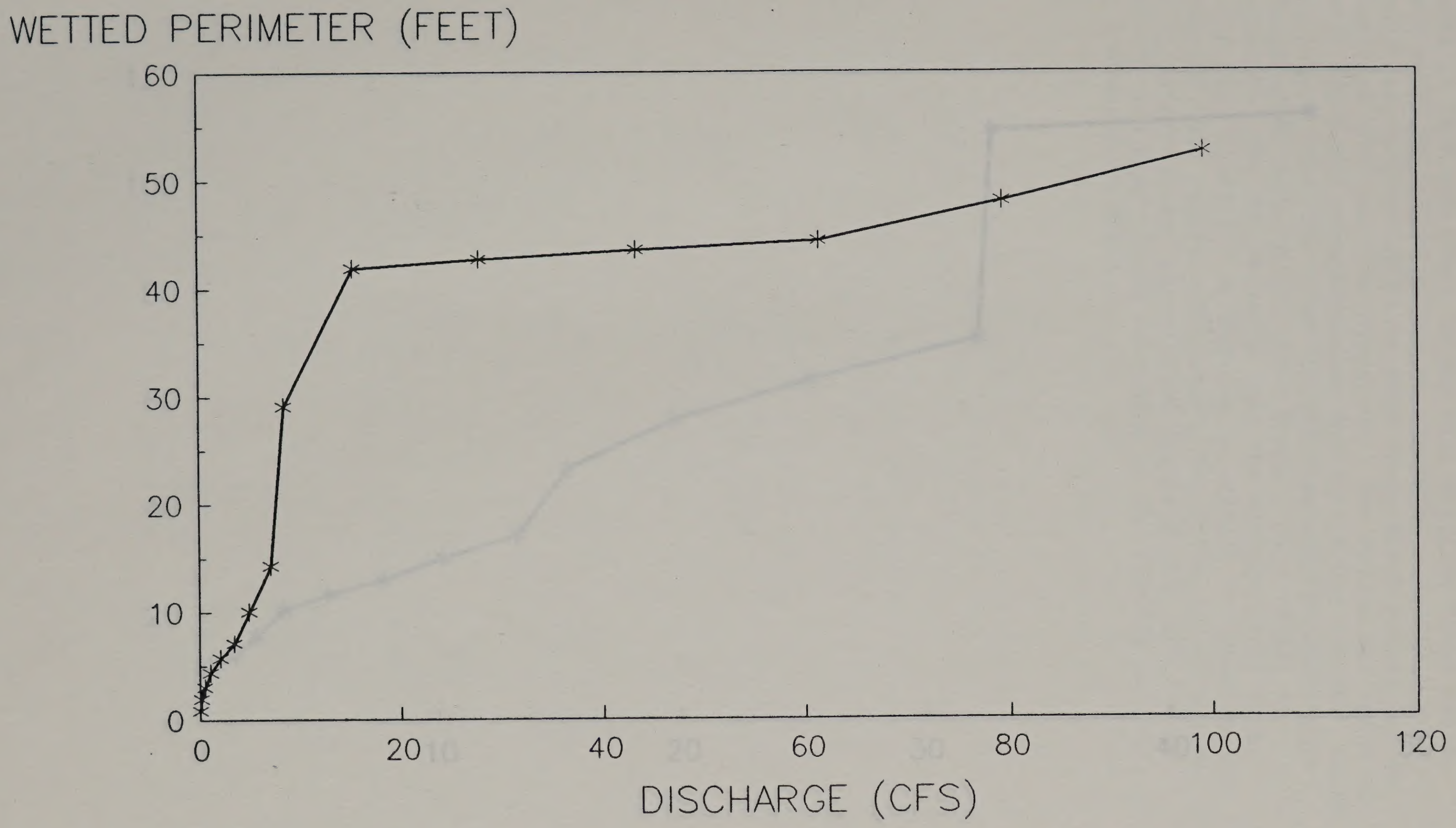
Figure 10.



N = .029

Figure 11.

BILL WILLIAMS RIVER
CROSS-SECTION #4
STREAM CHANNEL



N = .029

Figure 12.

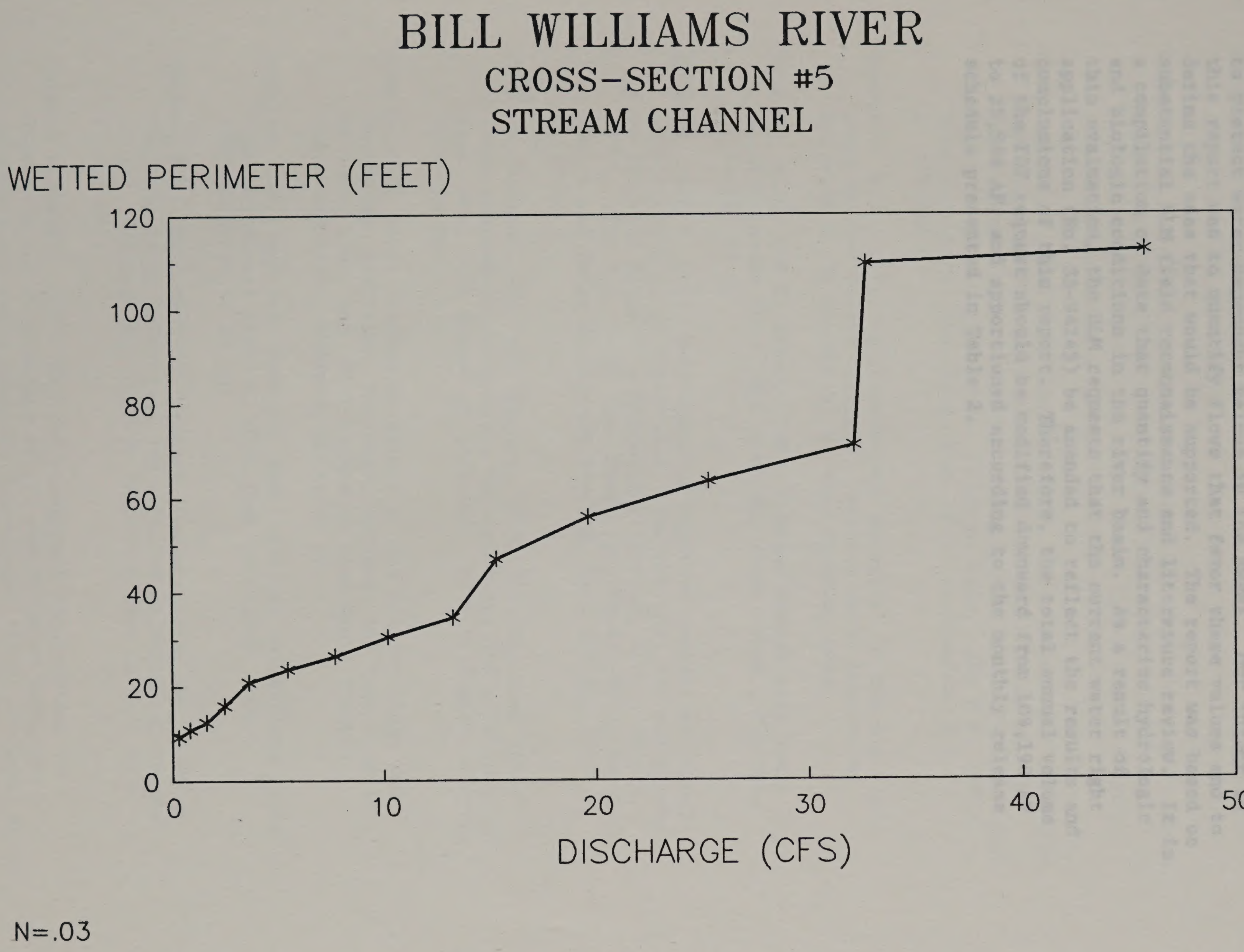

BILL WILLIAMS RIVER
CROSS-SECTION #5
STREAM CHANNEL
WETTED PERIMETER (FEET)
120
100
80
60
40
20
0
0
10
20
30
40
50
DISCHARGE (CFS)
N=.03

Figure 13.

Conclusion

Maintenance of instream flows in the Bill Williams River serves to protect water-dependent values in the BWRMA. Our intent in this report was to quantify flows that favor these values and to define the uses that would be supported. The report was based on substantial BLM field reconnaissance and literature review. It is a compilation of data that quantify and characterize hydrologic and biologic conditions in the river basin. As a result of this evaluation, the BLM requests that the current water right application (No. 33-94245) be amended to reflect the results and conclusions of this report. Therefore, the total annual volume of the ISF request should be modified downward from 109,190 AF to 25,548 AF, and apportioned according to the monthly release schedule presented in Table 2.

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Attachment 1.

Bill Williams River Field Assessment: Hydrology, Hydrogeology, and Geomorphology

by

William Jackson
and
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U. S. Bureau of Land Management

Service Center
Denver, Colorado

BILL WILLIAMS RIVER FIELD ASSESSMENT:
HYDROLOGY , HYDROGEOLOGY, AND GEOMORPHOLOGY

by

William L. Jackson and Paul Summers [1]

The Yuma District requested assistance from the Division of Resources in the analysis and quantification of instream flow needs for the Bill Williams River Riparian Planning Area. This report summarizes field observations made during the week of June 27-30, 1988, of hydrologic, geomorphic, and hydrogeologic conditions on the Bill Williams River between Alamo Dam and the National Wildlife Refuge. Our preliminary instream flow recommendations are also provided. Previous assistance was provided in the design of a conceptual (water balance-based) approach to quantifying instream needs for the Bill Williams River (memo 1382 [D-471], May 16, 1988), and in the preliminary stratification of river reaches for field sampling purposes. Also, in a memo to the Phoenix District hydrologist dated July 7, 1988, we provided reduced cross-section data collected during the field review, and a reanalysis of the Alamo Dam streamgage data for the post-dam period. This report reflects, in part, the collective observations of the field team. Team members included Jim Nye (Yuma DO), Barry Long and Lin Fehlmann (Phoenix DO), Mike Henderson (Havasu RA), and Becky Peck (Kingman RA). Robert Brumbaugh and T.J. Stetz of the Corps of Engineers, and Dan Dinkler of the U.S. Fish and Wildlife Service also participated in the field assessment. Dave Ellerbroek, Norma Reitsma, and Shirley Hudson of the Division of Resources assisted in field data reduction.

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Background

The Bill Williams River Riparian Management Area is located in the Basin and Range Lowlands physiographic province of western Arizona. The BLM-managed reach begins at Alamo Dam and runs roughly 20 miles downstream to the Planet Ranch (owned by the city of Scottsdale). Flows in the river are almost entirely regulated by the operation of Alamo Dam although ephemeral inflows and probably some underflow from tributary drainages occur unregulated. The reservoir's operation schedule calls for a 10-cfs base release or a release equivalent to reservoir inflows, whichever is less. Roughly 75,000 ac-ft. of stormflow are also released downstream. Post-dam discharge summaries at the Alamo Dam streamgage were provided to the Phoenix District hydrologist in a separate report. In general, median monthly flows reflect the reservoir operation schedule. Prior to dam construction in 1970, annual flows at the Alamo gage averaged 94 cfs. Baseflows (as indexed by the 90-day low flow) averaged 6.7 cfs.

In 1986, the state of Arizona (DWR) requested the Corps of Engineers to reevaluate the reservoir operation schedule. Subsequently the city of Scottsdale filed a water right application for the unappropriated stormflow releases, proposing that they be diverted from the Alamo Dam reservoir. In 1988, subsequent to the city of Scottsdale filing, BLM applied for an instream flow appropriation below Alamo Dam for flows ranging between 41 to 601 cfs, depending upon the month of the year. At the time of its filing, BLM indicated its intent to more thoroughly assess its instream flow needs and to modify its application if need be.

Hydrogeology of Bill Williams River

Ground water in the Bill Williams River Valley occurs primarily as underflow in alluvial basin-fill deposits that consist of boulder to pebble conglomerate with interbedded fine-to-medium-grained sands and silt deposits.

Geologic formations and structural features such as fractures that have been produced by faulting control the flow system. For example, the bedrock at the stream gage at Alamo Dam is very extensively fractured which allows some water to percolate downward from the stream into the regional aquifer. Reaches of gaining or losing stream are controlled by variations in bedrock and its proximity to the surface. The Planet Ranch area has been filled by gravels that probably contain rock fragments ranging in size from pebbles to large cobbles (1.25 in. to 10.08 in. using classification of Friedman and Sanders, 1978).

Streamflow losses along the reach from Alamo Dam to Planet Ranch are due mostly to geologic and geomorphic factors and do no represent large gains or losses in combined surface flow and underflow. Some losses are believed to be to the regional ground-water flow system, but these are not quantifiable without initiating a complex ground-water study. However, these losses are not believed to be very substantial.

In April 1951, the USGS made a seepage run along 30 miles of stream from Alamo to a rock constriction about 1 mile downstream from Planet Ranch. These data show that the stream was dry in Section 14 N.E. 1/4, T.10 N. 14 W.; however, the streamflow was measured at 10 cfs below Planet Ranch. The flow at the

Alamo gage was 8.94 cfs (Wolcott, Skibitzke, and Halpenny, 1956); thus, no significant losses occurred that removed water from the alluvial aquifer system. The slight gain recorded at the gage site below Planet Ranch could be attributed to ground-water input from Castaneda Wash on the east side of the valley at Planet Ranch.

The Bill Williams Valley is believed to be formed along a fault zone that allowed for relatively rapid downcutting of the otherwise highly resistant metamorphic rocks. This explains the unusually dense fracturing of the bedrock in the vicinity of the Alamo gage.

The valley at Planet Ranch is capable of storing an astonishing amount of ground water. Having large dimensions (6 miles long x 1.25 miles wide) and thick deposits of alluvium that are very permeable, the valley can store large volumes of water without experiencing large changes in the ground-water level. The storage volume can be calculated using the equation $V=SAdh$, where S=storage coeficient, A=surface area, and dh=the change in head in the aquifer. For example, if the water level is raised by 1 ft. in the valley fill, the amount of additional water taken into storage would be 312,855,420 gallons.

Although well owners have reported fluctuations of water level of as much as 30 ft. (Sanger and Littin, 1981), this is most likely due to ground-water mounding effects near the river. Such rises in the ground-water level are unlikely in such a large ground-water reservoir as at Planet Ranch. Because of this, these reported rises in the water table probably do not occur very far away from the river channel.

The following calculation of the amount of water taken into storage under a 1-ft. rise in the saturated thickness shows the extremely large amounts of water that are potentially stored in the Planet Ranch Valley:

$V=SAdh$

where: $S=.20$ (S = storage coefficient)

$A=7.5$ sq. mi. (for sediments 6 mi. long x 1.25 mi. wide)

$dh=1$ ft. (change in storage)

$V=312,855,420$ gal.

Ground-water Underflow

The cross section at Site 7 (at the east of Planet Ranch Valley) was used to determine the quantify of underflow that is passing into the Planet Ranch area. This site represents a reach of the stream where riparian vegetation has existed (but has been reduced due to livestock) and is particularly useful because of the straight reach and the well developed floodplain. The volume of water flowing through the alluvial deposits as underflow can be determined using the Darcy equation $Q=KIA$, where K is the hydraulic conductivity, I is the hydraulic gradient, and A is the cross-sectional area perpendicular to the flow path. Using a value of $K=31.2x10-3$ for coarse gravel (Mercer, Thomas, and Ross, 1982), which should be representative of conditions at this site, the flow of 28 cfs through the alluvium can be accounted for.

Using the following equation:

$Q=KIA$

where: $K=31.2 \times 10^{-3}$

$I=.002$

$A=(912 \text{ ft.} \times 150 \text{ ft.})$

$Q=18,100,763$ gal/day

$=12,569$ gal/min

$=28$ cfs

Interestingly, this value corresponds with the actual loss of flow from Alamo Dam to this cross-section location. However, this amount of underflow is based on a very high value of hydraulic conductivity and assumes no losses to the regional aquifer system. In actuality, there are likely some losses from underflow to the regional aquifer. The valley at Planet Ranch is substantially wider than the 900-ft.-wide cross section measured at Centennial Wash. If the hydraulic gradient is actually greater than .002 or if the thickness of the deposits is greater than the estimated 150 ft. at Centennial Wash (a more likely situation), then the underflow could approach the 80-cfs loss that we measured in the canyon at the west side of Planet Ranch in June 1988.

The surface-water flow system at the outlet of Planet Ranch does not respond to large changes in inflow at Planet Ranch by producing corresponding increases in surface flow. This is because of (1) the extremely large storage capacity of the alluvial sediments, (2) the very high hydraulic conductivity

of the sediments, and (3) the probable geologic control at the outlet that allows only a small portion of the saturated zone at Planet Ranch Valley to flow out.

The geologic control at the Planet Ranch outlet is an interesting one and has its origin in the postulated faulting that occurred several hundred thousand years ago. As mentioned earlier in this section, the Bill Williams River is believed to follow the trace of a fault or a zone of faulting that produced a line of weakness where the river rapidly cut down into the bedrock. Over thousands of years, downcutting likely produced a notch in the bedrock prior to filling the valley with sediment. This notch controls the rate of outflow from Planet Ranch downstream to the refuge. This factor, combined with the fact that great increases in water level in the sediments generally do not occur, accounts for the observed flow out of Planet Ranch being maintained at about 10 cfs no matter what the inflow is at the east side of Planet Ranch. Data taken by USGS (1951) confirms this outflow rate. The flow was at about 11 cfs during this study when the release from the dam was 100 cfs. The effect of all this is that the Planet Ranch Valley acts similar to a constant head boundary at that point in the flow system. Large inputs to the system at this point are moderated by the extremely high storage capacity of the fill. A nearly constant flow rate out of the valley downstream is the result.

In addition to the inflow to Planet Ranch from the river, there is a contribution from ground-water flow at Castaneda Wash. Water level data in one well about 6 miles north of Planet Ranch indicated a water level of 679 ft. (Sanger and Littin, 1981). This confirms a ground-water gradient exists between the well and the valley fill at Planet Ranch where the water level in

wells is generally at 605 ft. However, a hydrogeologic connection is not confirmed at this time because we don't know enough detail about possible perched aquifers or multiple aquifers in this area that may confound water level measurements and result in an erroneous interpretation of the hydrogeologic system. The potential for large contributions of flow via ground water from this source is very great; there is an extremely large drainage basin that extends north from Planet Ranch for about 10 miles. This area is covered with Tertiary and Quaternary sandstone, conglomerate, and unconsolidated sand gravel that should have the capacity to transmit large amounts of water. It is our belief that large contributions might be input to the Planet Ranch area from this drainage basin. These contributions are likely highly variable and likely exhibit much seasonal fluctuation.

This hydrogeologic flow system that provides water to Planet Ranch needs to be evaluated more fully if a clear understanding of the river dynamics and the ground-water/surface-water interactions is going to be achieved. However, for purposes of this study, the quantification of this component is not critical to the analysis. It may become an important factor if ground-water pumping at Planet Ranch is increased substantially. An accurate and complete accounting of the water balance might then be necessary.

Geomorphic Conditions

The Bill Williams River in the study reach is an alluvial stream, with a very mild gradient. The mild gradient combined with the presence of riparian vegetation and--we believe--the historic presence of beaver, provided the depositional environment for sediments delivered from tributary drainages.

Barren watershed conditions, combined with the steep tributary drainages and the ephemeral nature of runoff, resulted in considerable coarse sediment delivery. The alluvial valley bottom is subsequently coarse grained and very permeable. Where the valley fill is deep and wide, for example at Planet Ranch, considerable volumes of water can be stored and transported via underflow in the alluvial sands and gravels. Where the valley is narrow, for example at the gorge below Alamo Dam, alluvial deposits, though coarse, have lower storage capacity due to their smaller cross-sectional area and won't transmit high volumes of water as underflow.

As is typical of alluvial (depositional) streams, the Bill Williams River below Alamo Dam was historically characterized by lateral adjustment and migration. Features and processes such as meandering, bar development, channel migration, braiding, and channel realignment were probably common and are still abundantly evident below Lincoln Ranch.

Following construction of Alamo Dam, runoff peaks and sediment transport rates were greatly reduced. The stream channel responded to the decreased upstream sediment inputs by downcutting between Alamo Dam and the lower end of Lincoln Ranch. The streambed in this reach is now well controlled by cobble and boulder-sized materials. Width-to-depth ratios have been reduced, and main channel capacities have increased--meaning that few, if any, high flow releases now have access to the historic floodplain and riparian zone.

Downstream from Lincoln Ranch, the stream is adjusting to the reduced high flows by aggrading its bed (sediment inputs--both from the scoured reach upstream, and from side drainages--now exceed the transport capacity of the

river). The streambed is composed primarily of sand and fine gravels. Width-to-depth ratios increase dramatically, and main channel capacities appear to be lower. High flow releases have access to much of the historic floodplain and riparian zone downstream from Lincoln Ranch. Ongoing depositional processes are very pronounced in the vicinity of Planet Ranch/Centennial Wash--and are accentuated by the dramatic reductions in streamflow and sediment transport capacity in this reach.

Channel conditions and sedimentation processes interact significantly with riparian area conditions in the reach below Lincoln Ranch. Stream channel and floodplain conditions will be enhanced by riparian area conditions in this reach. Conversely, riparian vegetation will benefit from controlled channel adjustments and modest, periodic flooding.

Generalized Water Balance

A generalized water balance for the Bill Williams River study reach is depicted in Figure 1. Inputs occur primarily as releases from the Dam, with some limited volume tributary surface-water flows and ground-water inputs also occurring at various locations downstream. Outputs occur as (1) consumptive use by riparian vegetation, (2) evaporation, (3) percolation to deep ground water, (4) consumptive use for agricultural and domestic purposes, and (5) outflow at Planet Ranch. Outflow to Planet Ranch occurs as both surface flow (low volume) and ground-water flow through the stream alluvium (underflow).

Flow in the river at any place and point in time reflects not only inputs and losses, but a strong interaction between surface flows and underflows. Where valley bottom alluvium is deep and wide, underflow capacities in the alluvium

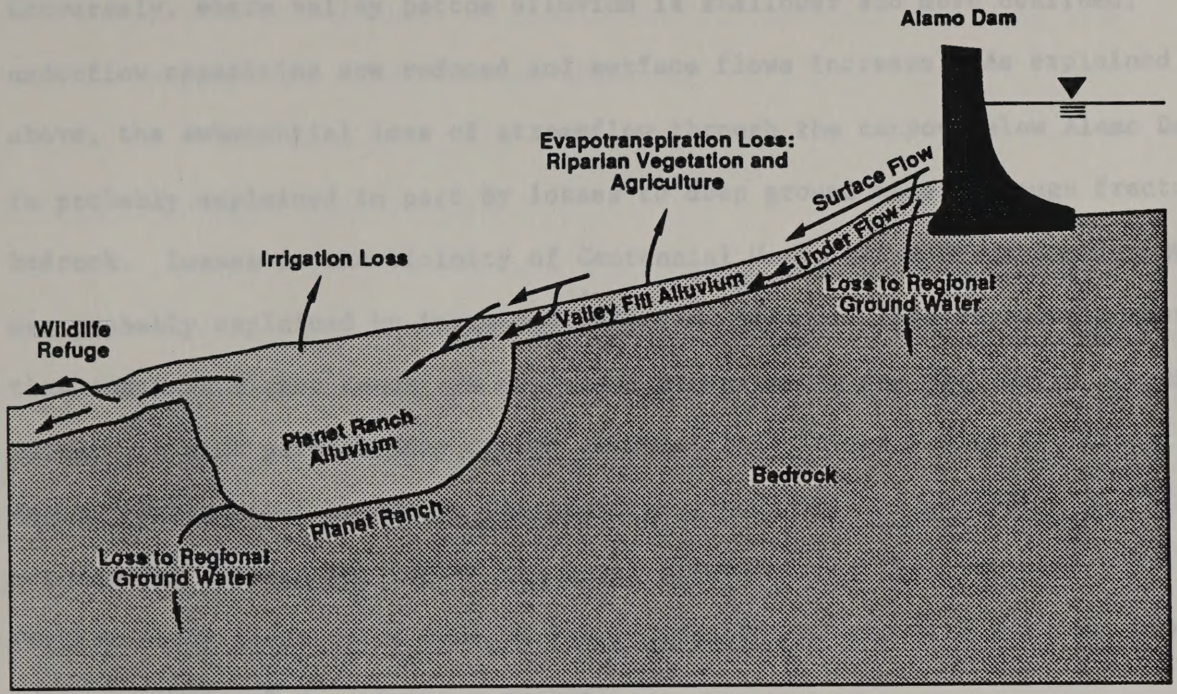

Figure 1. Conceptualization of major components of Bill Williams River water balance.

are large and surface flows are reduced by percolation into the alluvium. Conversely, where valley bottom alluvium is shallower and more confined, underflow capacities are reduced and surface flows increase. As explained above, the substantial loss of streamflow through the canyon below Alamo Dam is probably explained in part by losses to deep ground water through fractured bedrock. Losses in the vicinity of Centennial Wash, below Cross Section BW-6, are probably explained by increased underflow volumes. The enormous losses that occur at Planet Ranch are explained primarily by the very large storage volume and high permeability of the alluvial fill in the valley at Planet Ranch. Substantial losses to the regional ground-water flow system may also account for a large portion of the total flow declines that are observed. Further study needs to be done on the interaction of the Bill Williams River with the regional ground-water system.

Based upon our field observations and discharge measurements, and drawing from water budget data developed for the city of Scottsdale (Bill Stephens and Assc., 1988), it is our best judgement that roughly 10 cfs are required to meet evapotranspiration needs (riparian vegetation and agriculture) and percolation to deep ground water. Releases in excess of 10 cfs probably make it to Planet Ranch--either as surface flow or underflow. High releases probably recharge somewhat the floodplain aquifer in the study reach, and contribute to subsequent discharges to Planet Ranch. Similarly, high flows will provide substantial recharge of the alluvial aquifer beneath Planet Ranch because of the aquifer properties discussed above. We believe the present baseflow release of 10 cfs from Alamo Dam is inadequate in and of itself to meet downstream uses and losses (including those at the Wildlife Refuge and at

Planet Ranch). Water use by the Refuge and Ranch, in particular, have been maintained to a great degree by shallow aquifer recharge resulting from periodic higher-flow releases from Alamo Dam.

Riparian Condition and Potential

We believe the present deteriorated riparian conditions observed in the study reach cannot be attributed to the post-dam release schedule, but rather are the result of (1) geomorphic adjustments (described above) which occurred as the result of dam construction, and (2) effective management of livestock grazing in the riparian zone. However, we caution that altering the reservoir release schedule to reduce stormflow-period releases without compensating somewhat by increasing baseflow releases could adversely affect downstream water supplies and uses.

Presently, the best opportunities to enhance riparian conditions occur downstream from Lincoln Ranch, where channel capacities and floodplains are still in balance, and where riparian zone water tables are still intact due to a well developed floodplain. In addition to the broad alluvial zone in the vicinity of Centennial Wash, we would suggest that reaches of "gaining" streamflow downstream from Cross Section 3 might, from a water standpoint, have good riparian potential.

Recommendations

Instream Flows: It is our best judgement that a 25-cfs base release from Alamo Dam, combined with a 150-cfs high flow release in March, would be a minimum volume to meet downstream and instream water requirements, including

maintenance of the Planet Ranch aquifer, small baseflow releases to the National Wildlife Refuge, and enhanced riparian vegetation conditions in the BLM project area. Our water budget determinations suggest that a 25-cfs release would still result in the stream drying up in the vicinity of Centennial Wash during the growing season. However, we believe underflow in that reach might still be sufficient to maintain riparian water tables.

A 50-cfs base release would be an "optimum" release because it would maintain perennial flows throughout the project reach. This clearly would influence fishery and recreation values in reaches that otherwise would dry up. Under a 25-cfs release, however, instream flows would still be adequate to maintain and even enhance the present fishery (which has been established under conditions of a 10-cfs base release supplemented with normal high flows). The wetted perimeter data (provided under separate transmittal) suggest that a base flow between 10 and 32 cfs is adequate for fishery purposes. Flows between 10 and 30 cfs would be common above Cross Section BW-6.

The present 10-cfs release would, we believe, be inadequate to maintain both the existing fishery and enhanced riparian conditions, as well as downstream (Planet Ranch, Lincoln Ranch, Wildlife Refuge) needs, without frequent higher-flow releases as have occurred under the present operation schedule).

The 150-cfs March release is required for fine sediment flushing (the 105-cfs release was observed to be effective in transporting sands and fine gravels), fish spawning, and vegetation reproduction and establishment. Floodflow releases, which can be expected to occur periodically, should be adequate to maintain morphological features associated with channel adjustment and migration.

Land Use: Deteriorated vegetative conditions, resulting from ineffective livestock management, were observed throughout the study reach. Concomitantly, we observed vigorous cottonwood reproduction in reaches presently receiving rest from grazing. We believe it is essential that range management expertise be effectively represented on the Bill Williams Riparian Management Planning Team to assist in the evaluation of riparian conditions, the formulation of management objectives, and the development and evaluation of management alternatives.

Water Rights: The quantification in the present BLM water rights application is in error. That application should be formally modified at an early date to reflect numbers more in line with those determined by this project. This would indicate BLM's intent to be a reasonable party in discussions concerning the operation of Alamo Dam. Also, BLM needs to establish a constructive dialog with the Corps of Engineers, city of Scottsdale, National Wildlife Refuge, and state of Arizona concerning the allocation of water from Alamo Dam.

Additional Study: We believe the information gained during the field reconnaissance is adequate to support an instream flow water right application. Additional information, however, could further refine the quantification and substantiate our release recommendations. First, it is likely that water balance losses, to some extent, are a function of reservoir releases and season. Quantification of losses at other releases and at other times of the year could better develop our understanding of this phenomenon.

Secondly, we presently cannot distinguish--other than intuitively--between vegetation water requirements and losses to groundwater or throughflow. Quantification of losses during the vegetation dormant season could help quantify the components of water "loss."

Third, the status of the riparian water table in the Centennial Wash area and at Castaneda Wash needs to be established at times when surface flows are not present. Shallow observation wells could determine whether ground-water underflow in the alluvial channel is sufficient to maintain riparian vegetation, and whether seasonal fluctuations in the water level are significant.

Finally, evaluating zones of surface flow under the 10-, 25-, and 50-cfs baseflow release alternatives during both winter and summer seasons, could provide additional information on surface-water/ground-water interactions.

Again, we reiterate our belief that the team's field reconnaissance was very informative and productive, to which we credit all the individuals involved. The enthusiasm of all participants during this field study helped to make the study a great success. The hydrologic, hydrogeologic, and water rights issues on the Bill Williams River are very interesting. We thank you for involving us in this project and look forward to helping in the future in any way we can.

APPENDIX I

Bill Williams River
Summary Field Data[1]
June 27-29, 1988

Cross Section	Discharge, cfs	Inflection (Wet. Perim.-Q), cfs
1	105.5	15
2	91.0	20
3	86.4	10
4	93.9	15
5	93.7	32
6	86.2	no survey
7	76.1	10 est.
8	10.9	18
9	5.6	no survey

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1. Complete cross section survey results were sent to the Phoenix District hydrologist under separate cover.

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